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IS 14289 (1995): Manual tungsten inert gas arc welding of nickel and nickel alloys - Recommendations [MTD 12: Welding Applications]

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Indian Standard

MANUAL TUNGSTEN INERT-GAS ARC WELDING OF NICKEL AND NICKEL ALLOYS — RECOMMENDATIONS

(Second Revision)

UDC 621·791·753-871 : 669·24

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August 1995

Price Group 5

Arc Welding Applications and Thermal Cutting Sectional Committee, MTD 12

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Arc Welding Applications and Thermal Cutting Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This standard has been formulated with a view to serve as a guide for welding of nickel and nickel alloys by manual tungsten inert-gas arc welding process.

This standard prescribes details of material, equipment and general workmanship for manual welding of nickel and nickel alloys with argon as the shielding gas.

Additional data on manual tungsten inert-gas arc welding are given in Annex A for guidance.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

MANUAL TUNGSTEN INERT-GAS ARC WELDING OF NICKEL AND NICKEL ALLOYS — RECOMMENDATIONS

1 SCOPE

1.1 This standard covers the recommendations on material, equipment and general workmanship for the manual tungsten inert-gas arc welding of nickel and nickel alloys. The recommendations are primarily intended for general engineering applications for manual welding of nickel and nickel alloys with argon as the shielding gas.

1.2 This standard is not applicable for welding of tubes and pipes, and does not stipulate the allowable stresses in welds.

2 REFERENCES

The following Indian Standards are the necessary adjuncts to this standard:

IS No.	*Title*
812 : 1957	Glossary of terms relating to welding and cutting of metals
822 : 1970	Code of procedure for inspection of welds
1182 : 1983	Recommended practice for radiographic examination of fusion welded butt joints in steel plates (*second revision*)
5760 : 1983	Specification for compressed argon (*first revision*)
13007 : 1991	Tungsten electrodes for inert gas arc welding for plasma cutting and welding

3 TERMINOLOGY

For the purpose of this standard, the definitions as given in IS 812 : 1957 shall apply.

4 PARENT METALS, FILLER RODS AND WIRES

4.1 The parent metals that are covered in this standard and the corresponding filler rods and wires used for welding them are given in Table 1.

4.1.1 The filler rods and wires specified in **4.1** are for general purposes only. For special purposes, filler rods and wires may be used by agreement between the purchaser and the fabricator.

Table 1 Recommended Filler Rods and Wires for Nickel and Nickel Alloys

(*Clause* 4.1)

Base Metal	**Filler Metal**
Nickel (99·9% *Min*)	SNi-1
Monel (67Ni 30 Cu)	SNi-2
76Ni—8Fe—15·5 Cr	SNi-4
52Ni—2Fe—19Cr—3Al—3Ti—4Mo—19Co	SNi-5
56Ni—1Fe—19Cr—1Al—3Ti—4Mo—14Co	SNi-6
46Ni—18Fe—22Cr—9Mo—1·5Co	SNi-9

NOTE — For any special application of base metal, filler metal should be as per the agreement between the purchaser and the fabricator.

4.2 The filler rod and wire sizes and current ranges used to weld different thicknesses of parent metal are given in Table 2.

Table 2 Recommended Filler Rod and Wire Sizes and Welding Current Ranges for Butt Welds

Material Thickness mm	**Filler Rod/Wire Sizes** mm	**Current Range** Amperes
(1)	(2)	(3)
0·5	0·8	15-25
0·75	0·8-1·2	25-35
1·0	0·8-1·2	40-50
1·2	1·2-1·6	45-55
1·6	1·2-1·6	55-65
2·5	1·6-2·4	75-100
3·15	1·6-2·4	100-130
6·38	1·6-2·4	130-200
> 6·3	2·4-3·2	200-350

4.2.1 The filler rods and wires should be smooth, bright and free from grease and surface corrosion.

5 CURRENT CONDITION

5.1 Direct current equipment with the electrode connected to the negative pole shall be used for welding nickel and its alloys. Alternating current equipment may also be used.

5.1.1 If alternating current equipment is used for welding nickel and its alloys of lower thickness any device to suppress the direct current component should preferably be disconnected from the circuit.

5.1.2 High frequency spark generators are usually employed for arc striking. This unit enables the super imposition of a high voltage on the normal supply for a short time suitable enough for arc establishment. In case of a.c., the high frequency unit is continuously in operation in order to maintain the arc at each current reversal.

6 WELDING TORCH

6.1 Gas-cooled or water-cooled torches may be employed with ceramic or metallic nozzles Gas cooled torches are generally used for light gauge work with a short duty cycle whereas water cooled torches are used for higher currents and heavy duty cycles.

6.2 Ceramic nozzles are preferred over metallic nozzles since the later has to be separately water cooled and properly insulated.

6.2.1 All gas nozzles, of whatever material, should be kept clean at all times because an accumulation of foreign material on the inner surface and, particularly, on the tip of the orifice will eventually interfere with, or set up turbulence in the gas column or may begin to pass vaporized metal down into the weld puddle.

6.3 The use of gas lance is recommended for achieving laminar flow of the gas for more efficient shielding. This is suitable for narrower grooves and for long electrode extension.

7 ELECTRODES

7.1 Non-consumable electrodes made of tungsten are used because of its high melting point. Any of the grades given in Table 3 can be used depending on the nature of the job. Tungsten electrodes with 1 or 2 percent thorium or zirconium are superior to pure tungsten electrodes in several respects. They have higher electron emissivity, better current carrying capacity, longer life and greater resistance to contamination. With these electrodes, arc starting is easier and arc is also more stable. Two percent thoriated electrodes should be used with dc straight polarity (electrode negative). Pure tungsten or thoriated or zirconiated tungsten electrode should be used for welding with a.c..

Table 3 Codification, Chemical Composition and Identification Colour of Non-consumable Tungsten Electrodes

(*Clause* 7.1)

Codification (Refer IS 13007 : 1991)	Composition				Identification Colour
	Oxide Additive		Impurities Percent (m/m)	Tungsten Percent (m/m)	
	Percent (cm/m)	Nature			
(1)	(2)	(3)	(4)	(5)	(6)
E-WP			0·20	99·8	Green
E-WTh 4	0·35 to 0·55	ThO_2	0·20	Balance	Blue
E-WTh 10	0·80 to 1·20	ThO_2	0·20	Balance	Yellow
E-WTh 20	1·70 to 2·20	ThO_2	0·20	Balance	Red
E-WTh 30	2·80 to 3·20	ThO_2	0·20	Balance	Violet
E-WTh 40	3·80 to 4·20	ThO_2	0·20	Balance	Orange
E-WZ 3	0·15 to 0·50	ZrO_2	0·20	Balance	Brown
E-WZ 8	0·70 to 0·90	ZrO_2	0·20	Balance	White

NOTES

1 The oxides additives are generally finally dispersed in the tungsten matrix, but the so called composite electrodes are made up of a pure tungsten core with an oxide coating. This type of electrodes combines the qualities of pure tungsten with those of the tungsten containing oxides, but have the disadvantage that they cannot be tapered.

2 The composite electrodes shall be identified by a second, pink ring.

7.2 The tungsten electrodes should be clean and free from all contamination by the molten filler rod or parent metal. All contaminations should be dressed clean by light grinding. When using direct current with the electrode connected to the negative pole, the electrode tip should be ground to a point having an angle of approximately as shown in Fig. 1A. Alternatively, the tip may be chemically treated to attain the required angle. While using a c., the electrode should be used with a balled end (*see* Fig. 1B.).

7.2.1 To avoid contamination of the tungsten electrode and the work, it is preferable to establish the arc using a high frequency spark generator.

7.3 The electrodes employed should be of adequate size to carry the current required without over-heating the electrode. The maximum current for different electrode sizes are given in Table 4.

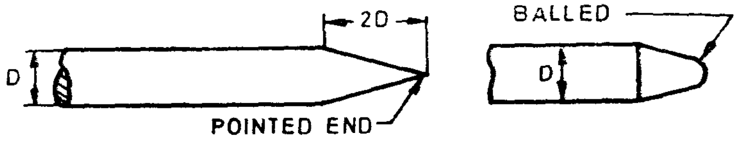
8 ARGON GAS

8.1 Quality

Argon gas conforming to IS 5760 : 1983 shall be used.

8.2 The rate of flow of argon should be adequate to obtain a clean weld. This depends on several factors, such as type of parent metal, current used, shape and size of nozzle, type of joint; and whether the work is done indoors or outdoors. Generally, a higher rate of flow is required with higher welding current for outside corner joints, edge welds and work outdoors. Flow rates of 6 to 8 litre per minute will be found sufficient to weld.

8.3 If tungsten inert gas welding has to be done outdoors during inclement weather, especially during period of high wind, the welding areas should be effectively protected. Droughts tend to break the gas shielding resulting in porous and oxide-contaminated welds.



1A Pointed End 1B Balled End

FIG. 1 RECOMMENDED ELECTRODE TIP PREPARATION

Table 4 Recommended Current Ranges Depending on the Electrode Diameter

(*Clause* 7.3)

Electrode Diameter mm	Direct Current, Amperes				Alternating Current, Amperes	
	Electrode Negative (−)		Electrode Positive (+)		Pure Tungsten	Tungsten with oxide additives
	Pure tungsten	Tungsten with oxide additives	Pure tungsten	Tungsten with oxide additives		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0·5	2-20	2-20			2-15	2 -15
1·0	10-75	10-75			15-55	15-70
1·6	40-130	60-150	10-20	10-20	45-90	60-125
2·0	75-180	100-200	15-25	15-25	65-125	85-160
2·5	130-230	170-250	17-30	17-30	80-140	120-210
3·2	160-310	225-330	20-35	20-35	150-190	150-250
4·0	275-450	350-480	35-50	35-50	180-260	240-350
5·0	400-625	500-675	50-70	50-70	240-350	330-460
6·3	550-875	650-950	65-100	65-100	300-450	430-575
8·0						650-830
10·0						650-830

9 PREPARATION OF PARENT METAL

9.1 Cleanliness is the single important requirement for successful joining of nickel and nickel alloys. So before joining or welding, joints should be cleaned thoroughly to remove all foreign substances such as oil, grease, dirt, paint, cutting fluid, machine lubricants, etc. Cleaning is done by degreasing, alkali, cleaning or both followed by wire brushing and scrubbing with hot water.

9.2 Nickel oxides and nickel sulphides, if formed at weld edge, should be removed as these oxides and sulphides melt at higher temperature and remain solid and cause defects in weld. These generally cannot be removed by wire hand brushing or power wire brushing, hence grinding or abrasive blasting or machining should be used.

9.3 Degreasing

Joints can be cleaned with solvent soaked rags to remove surface oil, grease and dirt, thorough vacuum degreasing can also be done. The solvent used can be perchloroethylene acetone or any suitable solvent. Care should be taken while using these solvents as they are inflammable. Care should be taken while selecting the solvent such that the traces do not produce hazardous fumes and gases under the arc heat.

9.4 Alkali Cleaning

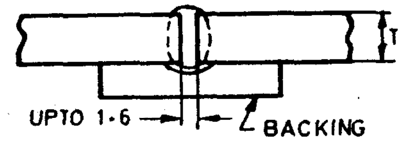
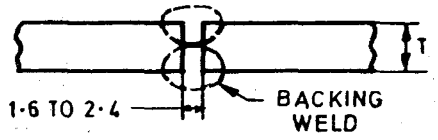
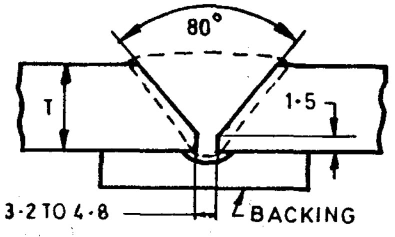
Paint and other material not soluble in degreasing solvent may call for alkali cleaning or cleaning with special proprietary compounds. After alkali cleaning the edge should be thoroughly cleaned to remove all residuals of cleaning agent.

9.5 Edge Preparation

Unlike ferrous weld metal, molten nickel/nickel alloy weld metal does not flow freely. This characteristic should not be compensated by extra heat input as serious loss of residual deoxidizers may result due to extra heat input. Hence to get proper penetration more root opening is required as compared to ferrous material. In general fillet welds and corner joints should be avoided.

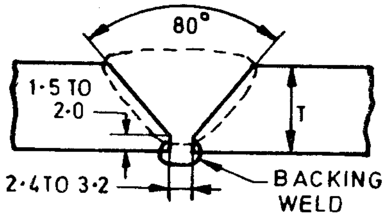
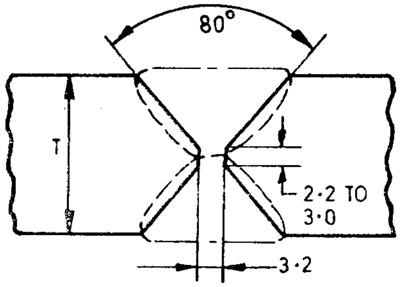
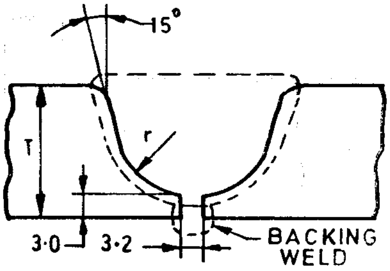
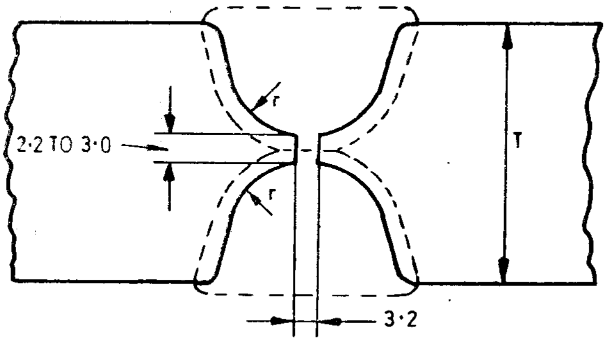
9.5.1 *Butt Welds*

It should be prepared in accordance with Fig. 2. The addition of filler metal is optional according to joint configuration and requirements.

Material Thickness T	*Edge Preparation*	*Remarks*
3.0 *Max*		With backing strip or ring
3·0 to 6·0		With backing weld
4·5 to 16		With backing strip or ring

All dimensions in millimetres.

FIG. 2 RECOMMENDED EDGE PREPARATION FOR BUTT WELDS (*Continued*)

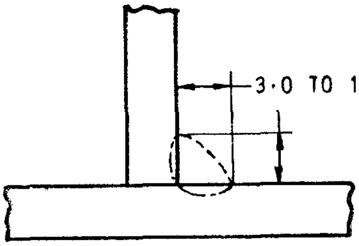
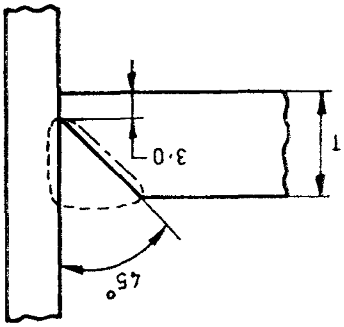
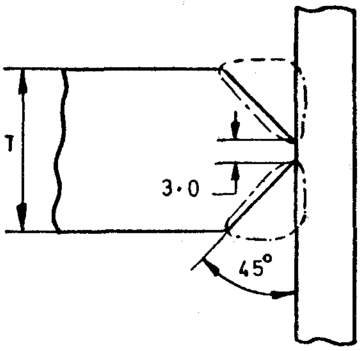
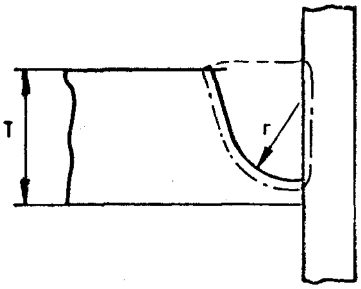
Material Thickness T	*Edge Preparation*	*Remarks*
6·5 to 16		With backing weld
12·5 to 32		Double V Groove
12·5 to 50		Single U Groove
25 to 60		Double U Groove

All dimensions in millimetres.

FIG. 2 RECOMMENDED EDGE PREPARATION FOR BUTT WELDS

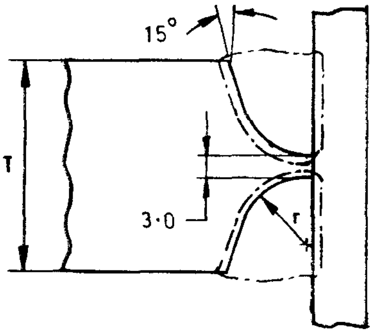
9.5.2 *T-Joints*

Illustrations regarding edge preparation of T-joints are given in Fig. 3. These joints are not recommended for lower thicknesses.

Material Thickness T	*Edge Preparation*	*Remarks*
Any		Fillet
6·0 to 25		Single bevel groove
12·5 to 50		Double bevel groove
25 to 64		Single J groove

All dimensions in millimetres.

FIG. 3 RECOMMENDED EDGE PREPARATION FOR T-JOINTS (*Continued*)

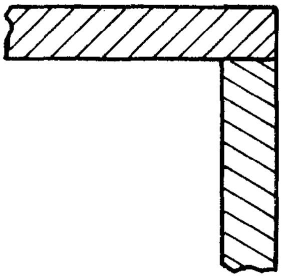
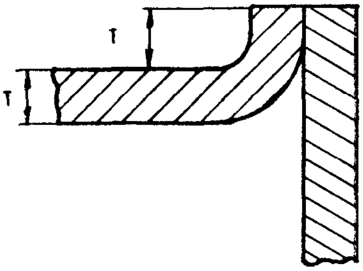
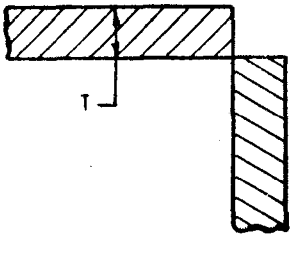
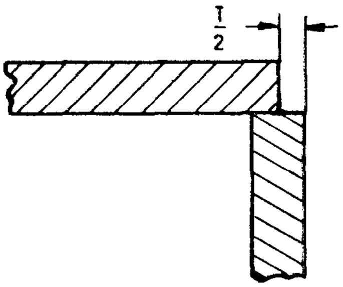
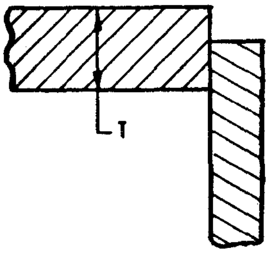
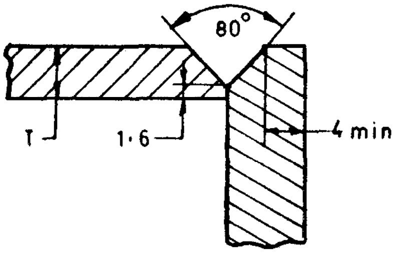
Material Thickness T	*Edge Preparation*	*Remarks*
25 to 64		Double J groove

All dimensions in millimetres.

FIG. 3 RECOMMENDED EDGE PREPARATION FOR T-JOINTS

9.5.3 *Corner Joint*

It should be prepared in accordance with Fig. 4. The filler material addition is optional depending upon the joint configuration and requirement.

Material Thickness T	*Edge Preparation*	*Remarks*
Up to 1·6	 	Filler wire addition optional
Over 1·6	 	Filler wire should be added
	 	Filler wire should be added

All dimensions in millimetres.

FIG. 4 RECOMMENDED EDGE PREPARATION FOR CORNER JOINTS

9.5.4 *Lap Joint*

It should be prepared in accordance with Fig. 5. Filler material should be added.

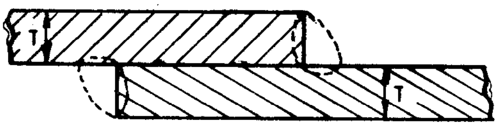


FIG. 5 RECOMMENDED EDGE PREPARATION FOR LAP JOINT

10 ASSEMBLY FOR WELDING

10.1 To maintain alignment during welding, the parts should be located by mechanical means or by tack welding.

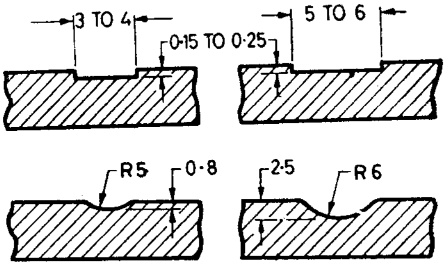
10.2 If a fixture is not used, the edge should be kept in alignment in assembly prior to welding by tack weld spaced at regular intervals along the joints. The tack welds should be either melted out during welding or made a part of and the same quality as the main weld. Defective tack welds should be removed before welding commences. After tack welding, the welds should be scratch-wire brushed before regular welding is commenced.

10.3 Backing bars, when employed, may be of removable copper and should be maintained in a clean condition free from grease, dirt, moisture and rust. Typical backing bars are illustrated in Fig. 6. Argon backing could be used with advantage specially with thinner gauges.

10.4 Argon used for back purging shall conform to IS 5760 : 1983.

11 PRE-HEAT AND INTER-PASS TEMPERATURE

11.1 Pre-heat is generally not required. However, warming up is to be done if the atmospheric temperature is less than 20°C.



All dimensions in millimetres.

FIG. 6 TYPE OF TEMPORARY BACKING BARS

11.2 For multipass welds, it should be ensured that the inter-pass temperature is maintained around 175°C.

12 PRECAUTIONS DURING WELDING

12.1 Argon and water supplies shall be opened a short while before starting the arc and kept open a short while after extinguishing the arc in order to ensure complete protection to electrode and weld puddle from atmosphere.

12.2 Argon, when employed for back purging, should have flow rates less than that of argon from the torch.

13 TESTING AND INSPECTION

13.1 The method of inspection should be in accordance with the requirements of IS 822 : 1970.

13.2 Welds not complying with such standards should be cut out, or repaired, as required, rewelded and reinspected.

13.3 The fabricator shall be responsible for the supply of material for testing, preparation of test piece, labour and appliances required for such testing as may be carried out in his premises by the purchaser. If such facilities are not available at his premises for carrying out such prescribed tests; the fabricator shall have the tests carried out elsewhere.

ANNEX A

(*Foreword*)

ADDITIONAL DATA ON MANUAL TUNGSTEN INERT-GAS ARC WELDING

A-1 GENERAL

A-1.1 The electrical equipment for tungsten inert-gas arc welding of nickle and nickle alloys comprises an alternating current or direct current power sources as the case may be, and a device for high frequency spark starting. These devices ensure a balanced and stable arc.

A-1.2 Care should be taken that air is not entrained into the argon stream through leaks in the connections or leads. The size of the nozzle used should give adequate coverage of the weld area with the shielding gas. The tungsten electrode should be clean. If it should get contaminated during welding, an arc should be drawn on a similar piece of material for a short while to clear contamination. If this method proves unsuccessful, the contaminated electrode should be lightly ground till the surface is once again clean. Argon cylinders should never be used below a pressure of 0·15 MPa (1·5 kg/cm^2) because of the danger of atmospheric contamination.

A-2 DETAILS OF THE PROCESS OF WELDING

A-2.1 Properties of Tungsten Inert-Gas Arc Welds

Strength of any particular welded joint will depend on several factors including the skill of the welder and the size of the pieces being joined. The welder's skill influences the quality of the weld and this, as well as the size of the weld required affects the amount of heat put into an assembly and subsequently the extent of annealing of the parent material. Thus, when high quality joints are a critical requirement, the weld strength requirements should be specified and checked by tests, and subsequently workmanship kept to the same standard by frequent and capable inspection.

A-2.2 Faults in Tungsten Inert-Gas Arc Welds

The chief faults found in unsatisfactory welds are gas porosity, oxide inclusion, cracks and undercutting, but they can be avoided by attention to welding procedure and by the choice of satisfactory parent metal and filler rod. The appearance of the surface is a good guide to the quality of the weld, the absence of discolouration, 'dirty' edges and under cutting being readily observed. The upper surface of the bead should be smooth with uniform ripples marks evenly spaced, and the underside free from crevices or excessive 'run through'. The form of the ripples is an indication of the speed of welding for given material and dimensions, and is also a guide to the grain structure of the weld metal.

A-3 APPLICATION

The tungsten inert-gas arc welding process has been widely adopted and the following industries represent a few of these:

a) Plant for the chemical and food industries;

b) Pipings;

c) Marine;

d) Aircraft, spacecraft and launch vehicles;

e) General engineering including castings;

f) Pressure vessels, boilers and heat exchangers; and

g) Atomic energy and nuclear power.

A-4 ADVANTAGES OF TUNGSTEN INERT-GAS ARC WELDING

The advantages of tungsten inert-gas arc welding, specially as applied to nickel and alloys, can be summarized as follows:

a) Ideal for joining thin materials, sometimes even without filler wire addition;

b) There is no slag formation;

c) There is no spatter as the filler material added in the weld pool;

d) Enables single sided welding with full penetration;

e) Simple edge preparations are sufficient;

f) Loss of alloying elements is much less than in other processes like metal-arc and gas-welding;

g) Less finishing costs (hardly involves operations like grinding, etc);

h) Suitable for welding in all positions; and

j) The process lends itself to many forms of automatic or semi-automatic weldings.

A-5 LIMITATIONS OF TUNGSTEN INERT-GAS ARC WELDING

The following are the limitations of tungsten inert-gas arc welding:

a) The cost is comparatively high because of slow speed and high cost of argon gas and tungsten electrodes;

b) The equipment is rather more complicated, and hence higher initial cost than that required for shielded metal arc or oxy-fuel gas welding;

c) The process cannot be well used on site work, unless precautions are taken to avoid draughts;

d) The process is not suitable for thick sections because of low deposition rates; and

e) The operation requires adequate care to prevent electrode or base metal contamination.

A-6 SOME TYPICAL PROBLEMS, THEIR CAUSES AND REMEDIES

Some common problems in tungsten inert-gas arc welding, their likely causes and suggested remedies are given in Table 5.

A-7 SAFETY PRECAUTIONS

A-7.1 The ultra-violet rays emitted during tungsten inert-gas arc welding of stainless steel are much more intense than those formed during the manual arc-welding of steel because higher current densities are used. For this reason, the operator should use protective gloves and darker shade of protection glass. Use can also be made of suitable chemical agents like light deflectant creams — available for protection against ultra-violet radiations.

A-7.2 During the welding of material which has been degreased with trichloroethylene, highly toxic and poisonous fumes will be encountered which cause severe headaches. For this reason, degreasing with this reagent should be carried out in a different room from the welding operation, and all material which has been so degreased should be either hot dried or allowed to stand for sufficiently long time at room temperature to ensure that the material is completely free of degreasing solvent.

Table 5 Trouble Shooting Guide for Tungsten Inert-Gas Arc Welding

(*Clause* A-6)

Problem (1)	Cause (2)	Remedy (3)
Wasteful electrode consumption	Improper shielding (resulting in oxidation of electrode)	Clean nozzle, bring nozzle closer to work, step up gas flow
	Operating on reverse polarity	Employ larger electrode or change to straight polarity
	Improper size electrode for current required	Use larger electrode
	Excessive heating in holder	Ground finish electrode; change; collect check for improper collect contact
	Contaminated electrode	Remove contaminated portion, erratic results will continue as long as contamination exists
	Electrode oxidation during cooling	Keep gas flowing after stoppage of arc for at least 10-15 seconds
		Rule 1 second for each 10 amperes
Erratic arc	Base metal is dirty, greasy	Use appropriate chemical cleaners, wire brush or abrasives
	Too narrow joint	Open joint groove; bring electrodes closer to work; decrease voltage
	Electrode is contaminated	Remove contaminated portion of electrode
	Too large diameter electrodes	Use smaller diameter electrodes
	Arc too long	Bring holder closer to work to shorten arc
	Improper electrode tip shape	Grind tip suitably
Porosity	Entrapped gas impurities (hydrogen, nitrogen, air, water vapour)	Blow out air from all lines before striking arc; remove condensed moisture from lines; use welding grade (99·999) inert gas
	Possible use of old acetylene hoses	Use only new hoses, acetylene impregnates hose
	Gas and water hoses	Never interchange water and gas hoses (colour coding helps)
	Oil film on base metal	Clean with chemical cleaner not prone breakup in arc, DO NOT WELD WHILE BASE METAL IS WET
	Inadequate gas flow rate	Set correct gas flow rate
	Contact starting with electrode	
Tungsten contamination of work piece	Electrode melting and alloying with base metal	Use high frequency starter; use copper striker place
	Shattering of electrode by thermal shock	Use less current or larger electrodes, use thoriated or zirconium-tungsten electrode
		Certain electrode ends are not slivered or cracked when using high current values
		Use embrittled tungsten to facilitate easy and clean breakage
Crater cracks	Abrupt arc stopping	Use down sloping current
	Contamination by sulphur, lead, phosphorus or low melting point materials	Clean the workplace thoroughly

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